LA-12058-MS

Stability Indices for Limited Strikes

19980513 158

Los Alamos

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

U3038

Prepared by Bo West, P Division

An Affirmative Action/Equal Opportunity Employer

Accession Number: 3038

Publication Date: Mar 01, 1991

Title: Stability Indices for Limited Strikes

Personal Author: Canavan, G.H.

Corporate Author Or Publisher: Los Alamos National Laboratory, Los Alamos, NM 87545 Report Number: LA-12058-MS

Report Prepared for: U.S. Dept. of Energy

Descriptors, Keywords: Limit Strike ALPS Attack Stability Missile Aircraft Interceptor Model Defense

Pages: 00022

Cataloged Date: Jul 18, 1991

Contract Number: W-7405-ENG-36

Document Type: HC

Number of Copies In Library: 000001

Record ID: 22291

Source of Document: DoE

LA-12058-MS

UC-900
Issued: March 1991

Stability Indices for Limited Strikes

Gregory H. Canavan

Los Alamos Los Alamos National Laboratory
Los Alamos,New Mexico 87545

CONTENTS

STABILITY INDICES FOR LIMITED STRIKES

by

Gregory H. Canavan

ABSTRACT

This note uses the formalism derived earlier to discuss the stability indices for limited strikes of varying magnitudes. They exhibit monotonically increasing stability indices, which increase much faster than those for large strikes. When the restrike uses the same number of missiles and aircraft as the first strike, the resulting stability indices remain unity to within small model-dependent factors.

I. INTRODUCTION

Earlier papers have derived a formalism for discussing the stability indices for all-out strikes in the presence of varying levels of defenses.[1,2] This note uses that formalism to discus stability indices for limited strikes of varying magnitudes. The results are qualitatively similar to those for all-out strikes, although limited strikes' defenses in conjunction with variable restrikes can maintain stability indices near unity for significant ranges of attacks.

II. ANALYSIS

Limited strikes can be treated to first order by reducing the number of attacking missiles and bombers in the equations

derived in "Crisis Stability Indices,"[3] apart from a few modifications treated below. The equations presented in that note are for the simultaneous launch of fixed but arbitrary numbers of missiles and aircraft against two-layer defenses. The first, boost-phase layer is treated as random subtractive; the second is taken to be preferential and adaptive, in accord with the characteristics of interceptors and sensors under development.

The attacker and defender are assumed to have equal offensive and defensive forces. Offensive forces are roughly at START levels; defenses are at the limited levels proposed to address them.

The model treats both land- and sea-based missiles. Missile boost and midcourse penetration probabilities are as derived before. The initial attack is assumed to consist primarily of land-based missiles and alert aircraft. Sea-based missiles would penetrate about as well for START levels but are assumed to be reserved for follow-on strikes.

The attacker strikes with some fraction of his missile force and alert aircraft. The strike is directed in roughly equal portions against the defender's missiles, aircraft, and military value targets. After riding out the attack, the defender restrikes with a corresponding fraction of his surviving missiles and aircraft. The restrike is directed about equally towards the striker's aircraft and value. The results are somewhat sensitive to the attack and defense allocations assumed, but earlier calculations have shown that those sensitivities are less than those to the aggregate offenses and defenses.[4]

III. REDUCED ATTACK SIZE

This section discusses the impact of reducing the strike and restrike sizes to 100 missiles with 10 RVs each. For ease of comparison, Figs. 1-14 correspond directly to those for all-out attacks in "Crisis Stability Indices."

Figure 1 shows the missile penetration probability, p. It falls off much more rapidly with the number of boost-phase

defenders, K, than that for all-out attacks because boost-phase defenses are more efficient against smaller launches. Figure 2 shows the missile first strike on value targets, which is reduced correspondingly. Even for I = 0 preferential defenders the first strikes on value are reduced to a few tens of weapons. For I > 500 interceptors they are eliminated altogether. Figure 3 shows that beyond about 1,000 SBIs the first strike is almost all from the 1,500 aircraft weapons assumed.

Figure 4 shows the defender's aircraft survivability, which is significantly higher than that for large strikes. By K = 2,000 interceptors, about 80% of the aircraft survive even without a preferential underlay. For I > 0 the survival probability is near unity for K > 500. Figure 5 shows the aircraft restrikes on value, which are close to the full 1,500 aircraft weapons for most defenses.

Figure 6 shows that missile survivability is also increased significantly. However, Figs. 7 and 8 show that the missiles' probability of surviving and penetrating the boost-phase defenses overhead is small beyond about 1,000 SBIs. Figure 9 shows that as a result the missile restrike on value is small except for I = 0. The total restrike on value in Fig. 10 is almost all from aircraft except for very small defenses, where by Fig. 4 the aircraft prelaunch survivability is suppressed. Figure 11 shows that the first striker's non-alert aircraft also generally survive to add to his first strike.

Figure 12 shows the first strike cost, which rises monotonically with K for all I and asymptotes at about 0.68 for K > 500 for I > 0. Figure 13 shows that the restrike cost falls monotonically for all I, falling to about 0.68. The two asymptotes are about equal since for K > 500 both reduce to the delivery of essentially the maximum number of aircraft weapons--and little else--on each other's value targets.

Figure 14 shows the resulting crisis stability indices, which increase rapidly with K for all I and with I for all K. For all but I = 0 the indices are all near unity for all K > 0.

Thus, limited strikes appear to exhibit monotonically increasing stability with defenses, and the indices increase much faster than for large strikes. Moreover, the calculations above were performed in a fashion that underestimated stability against limited strikes. That is discussed below, after the next section's discussion of the variation of the stability indices with attack size.

IV. VARIATION WITH ATTACK SIZE

This section studies the variation of attack parameters and stability indices with the number of attacking missiles and aircraft. Missiles are varied from $M = 50$ to $M = 250$; the attacking aircraft are varied proportionally.

Figure 15 shows the boost phase penetration probability as a function of M. The top curve is for $I = 250$ and $K = 500$; the lower is for a larger defense with $I = 500$ and $K = 1{,}000$ interceptors. Larger M eventually saturate given defenses. For the smaller defense p increases from about 30% to 80%.

Figure 16 shows the reduced defensive missile survival probabilities that result. For the smaller of the two defenses it falls from $M > 0$ to about 0.4 by an attack of 150 missiles. That is still much larger than typical survival probabilities for large attacks. For the larger defense it falls from $M > 120$ to ≈ 0.5 by about 250.

When penetration of the defenses overhead is included, as in Fig. 17, the overall probability is peaked, but falls rapidly. For the smaller defense it is $\approx 32\%$ at $M = 80$; for the larger defense the peak is about 35% at $M = 130$. The gain in prelaunch survivability with larger defenses is just about offset by the decrease in the boost-phase defense penetration probability.

Figure 18 shows the aircraft prelaunch survivabilities of the two sides' nonalert aircraft. At the left margin the bottom curve is the defender's prelaunch survivability, which decreases monotonically as an increasing fraction of the attacking missiles penetrate. The top curve is the attacker's prelaunch survivability, which decreases and then plateaus at about 0.7 as

the number of penetrating restrike missiles is reduced. The two other curves to the right are for the larger defenses.

Figure 19 shows the number of restriking RVs. It increases with M for small attacks as the defenses become less efficient, then saturates as penetration losses increase.

Figure 20 shows the first strike costs. They also increase for small M and then plateau, at higher levels for larger defenses. Figure 21 shows the second strike costs, which increase monotonically as fewer missiles survive and penetrate.

Figure 22 shows the stability indices. The lower curve for the smaller defenses falls throughout, reaching about 0.65 by M = 250. The upper curve for the larger defenses falls for M > 130, reaching about 0.85 at M = 250. The values for M = 100 agree with those on Fig. 14. The logical content of both sets of curves is that when the defenses are too small to address the attack, the stability index is reduced. Modest increases in the defenses appear capable of offsetting the effect.

V. RESPONSIVE RESTRIKES

The calculations of the previous section were done in a way that minimized the stability indices for limited strikes. In them the restrikes were composed of the surviving fraction of a number of missiles and aircraft equal to that used by the first striker. Thus, the number used in restrike was less by the prelaunch survivability of the restrike missiles and aircraft than the number used in the first strike. The difference can be on the order of a factor of two for large strikes, which leads to the reduction of restrikes and stability indices shown. This section alters the restrike to use the same number of missiles and aircraft as were used in the initial strike.

Figure 23 shows the number of restriking RVs, which increases monotonically, in contrast to the limiting behavior seen in Fig. 19. For the larger defenses the increase is about a factor of two by M = 150; a factor of 4 by M = 250. Figure 24 shows the total restrikes, which are similarly increased.

Figure 25 shows first strike costs. For both defenses they increase monotonically with M rather than plateauing as in Fig. 20. By M = 250 for the larger defenses the first strike costs are higher by a factor of $0.9/0.76 \approx 1.18$. For the smaller defenses they are higher by a factor of $0.9/0.62 \approx 1.45$.

Figure 26 shows the second strike costs. They still increase monotonically, though at a slower rate than those in Fig. 22. A comparison of Figs. 25 and 26 shows that with adjustment of the restrike the first strike costs track but are slightly higher than the second strike costs.

Figure 27 shows the resulting stability indices, which remain unity to within small model-dependent factors. The reason the indices go slightly above unity is that the missile component of the first strike is divided between the defender's missiles, aircraft, and value, while that of the restrike is only divided between the striker's aircraft and value, giving a slightly larger second strike on value. If the allocations were made symmetrical, the index would be identically unity. Thus, the departure from unity gives a rough measure of the sensitivity of the results to attack and defense allocations. The detailed sensitivity is much as examined elsewhere.[5]

VI. SUMMARY AND CONCLUSIONS

This note uses the formalism derived earlier for large exchanges to discuss stability indices for limited strikes of varying magnitudes. Limited strikes can be treated to first order by reducing the number of attacking missiles and bombers. The attacker and defender are assumed to have equal offensive and defensive forces. After riding out the attack, the defender restrikes with a corresponding fraction of his surviving missiles and aircraft.

Limited strikes exhibit monotonically increasing stability with defenses, and the indices increase much faster than those for large strikes. For fixed restrikes, the stability indices fall with attack size. When the defenses are too small to address the attack, the stability index is reduced. Modest

increases in the defenses appear capable of offsetting the effect. When the restrike is adjusted to use the same number of missiles and aircraft as the first strike, first strike costs are increased, second strike costs are reduced, and the resulting stability indices remain unity to within small model-dependent factors.

The results are qualitatively similar to those for all-out strikes, although limited strikes in conjunction with variable restrikes can maintain stability indices near unity for significant ranges of attacks. Thus, the stability of defenses against limited attacks is generally greater than that against large scale attacks.

REFERENCES

1. G. Kent and R. DeValk, "Strategic Defenses and the Transition to Assured Survival," RAND Report R-3369-AF, October, 1986.

2. G. Canavan, "Crisis Stability Indices for Adaptive Two-Layer Defenses," Los Alamos National Laboratory report LA-11974-MS, September 1990.

3. G. Canavan, "Crisis Stability Indices for Adaptive Two-Layer Defenses," op cit.

4. G. Canavan, "Crisis Stability Indices for Adaptive Two-Layer Defenses," op cit., Section VII.

5. G. Canavan, "Crisis Stability Indices for Adaptive Two-Layer Defenses," op cit., Section VII.

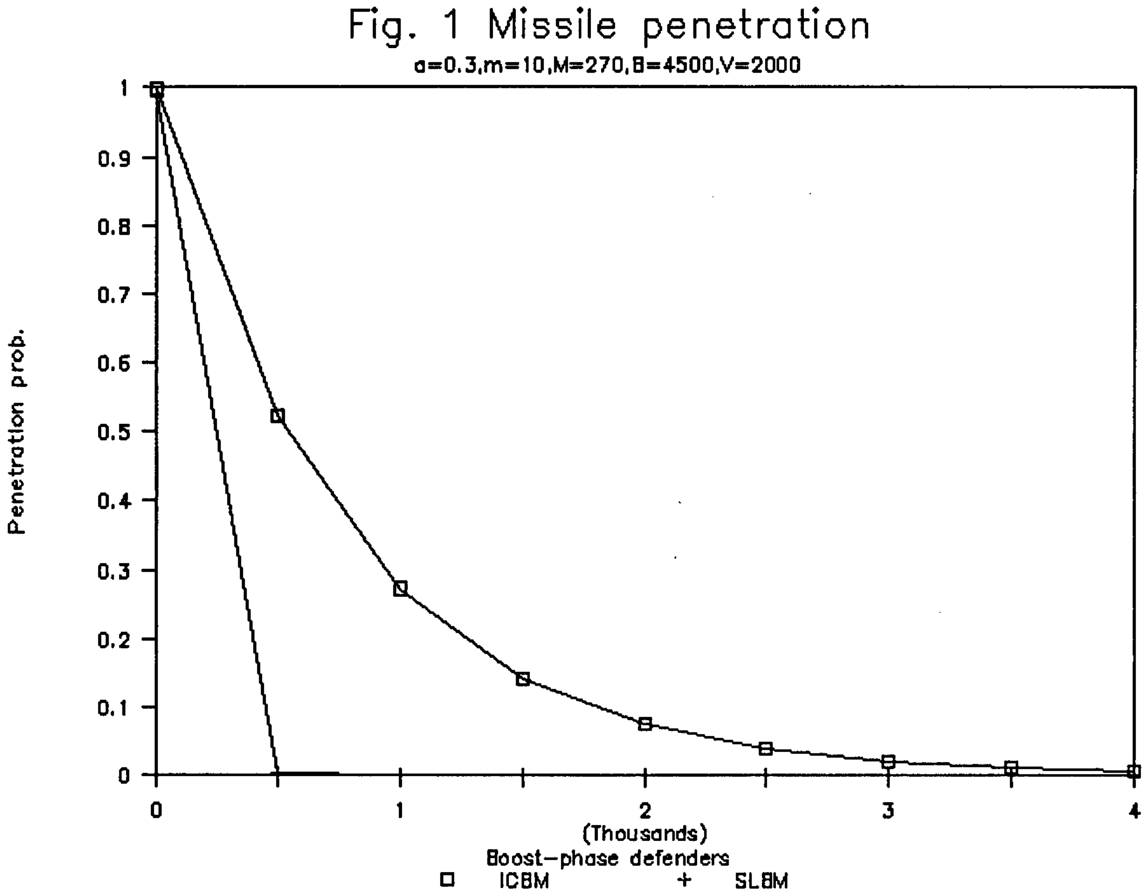
Fig. 1 Missile penetration
a=0.3,m=10,M=270,B=4500,V=2000
Penetration prob.
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
(Thousands)
Boost-phase defenders
ICBM
SLBM

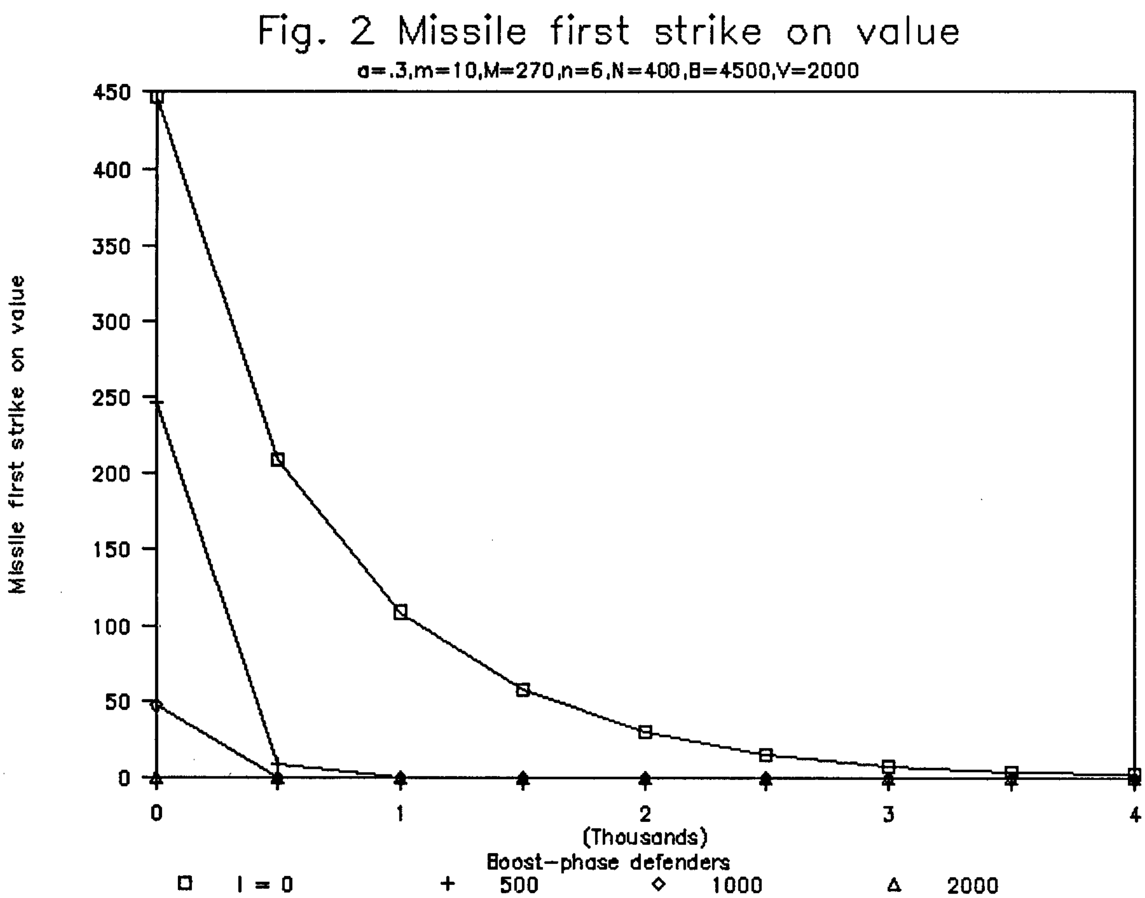
Fig. 2 Missile first strike on value
a=.3,m=10,M=270,n=6,N=400,B=4500,V=2000
Missile first strike on value
450
400
350
300
250
200
150
100
50
0
0
1
2
3
4
(Thousands)
Boost-phase defenders
I = 0
500
1000
2000

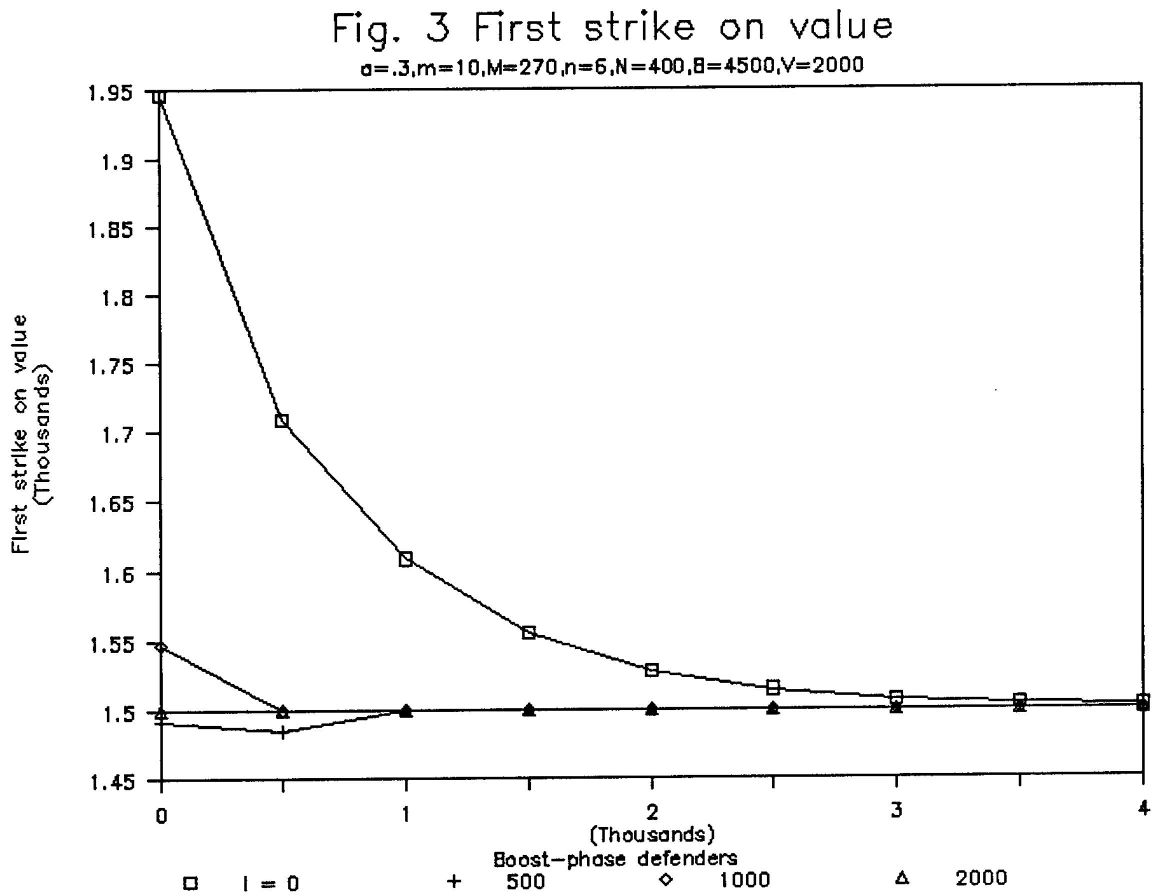
Fig. 3 First strike on value
a=.3,m=10,M=270,n=6,N=400,B=4500,V=2000
First strike on value
(Thousands)
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
0
1
2
3
4
(Thousands)
Boost-phase defenders
I = 0
500
1000
2000

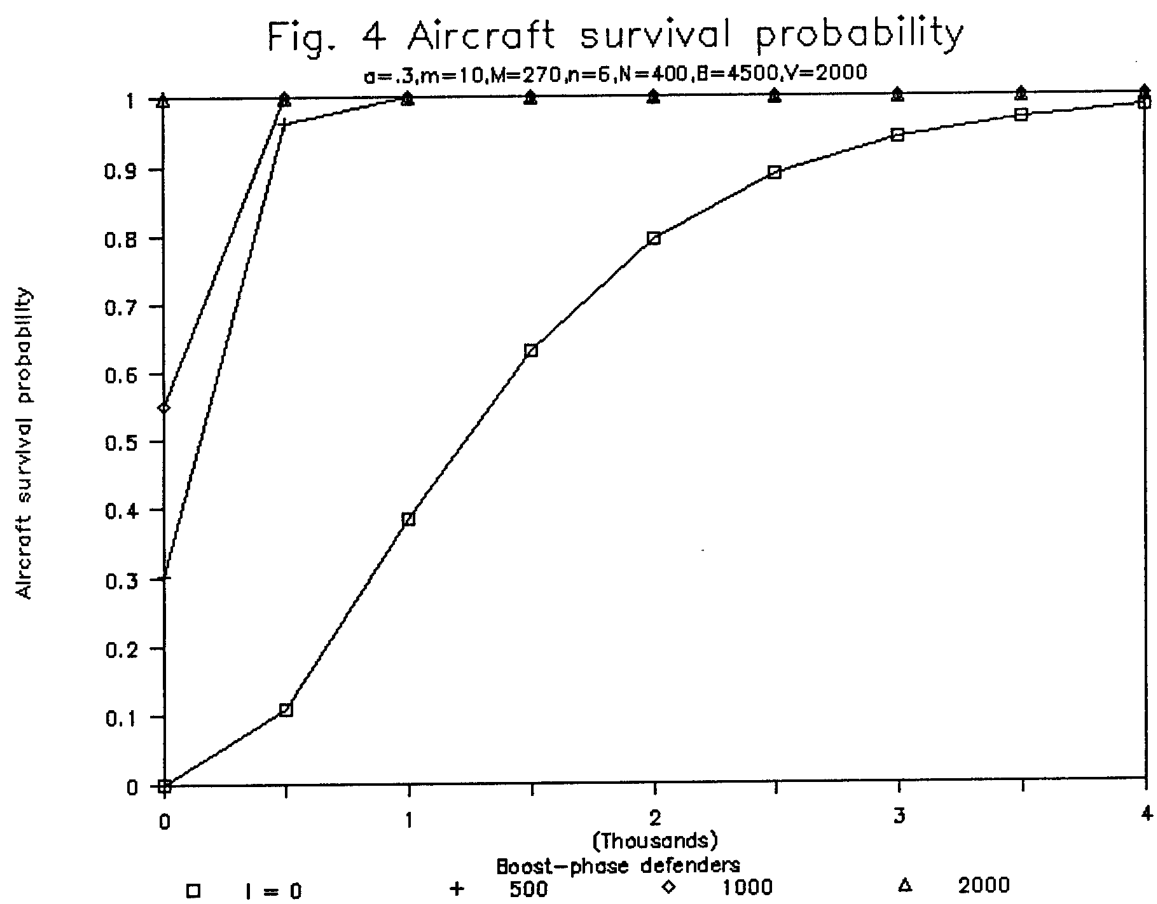
Fig. 4 Aircraft survival probability
a=.3,m=10,M=270,n=6,N=400,B=4500,V=2000
Aircraft survival probability
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
(Thousands)
Boost-phase defenders
I = 0
500
1000
2000

Fig. 5 Aircraft restrike on value

a=0.3,m=10,M=270,B=4500,V=2000

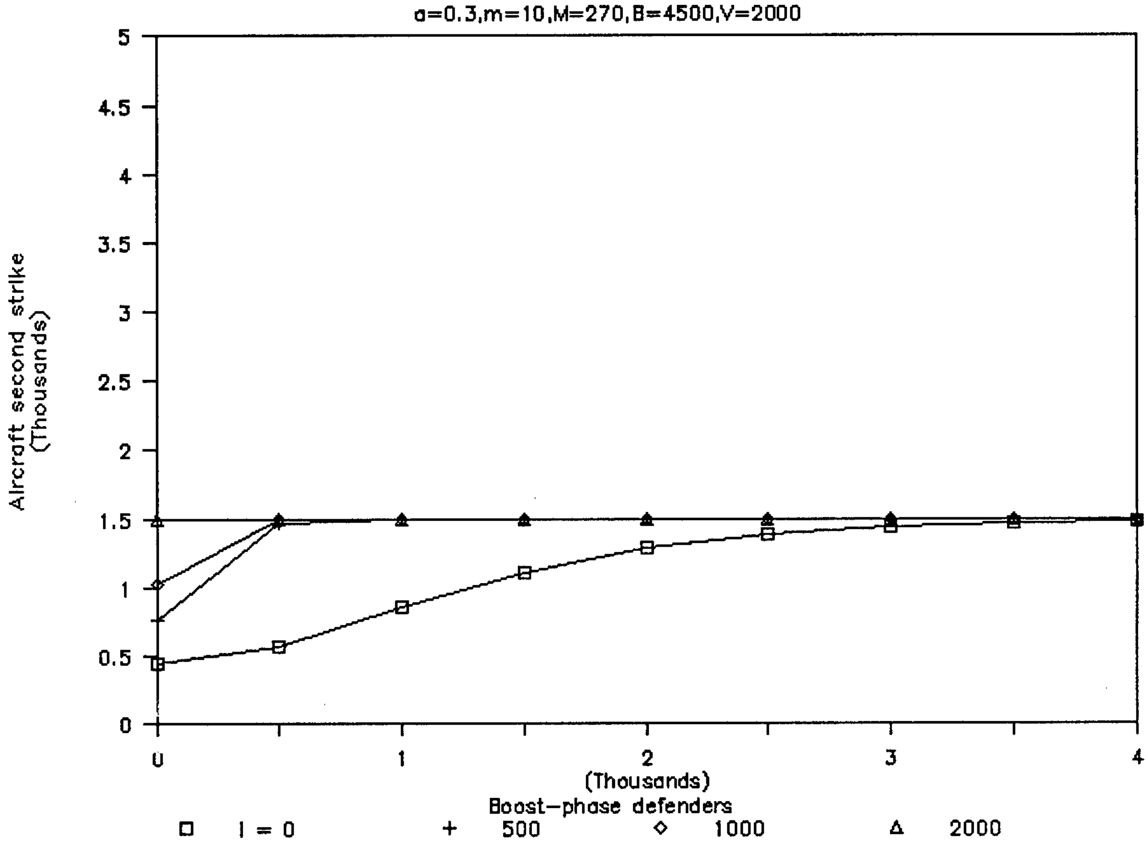

Fig. 6 ICBM survival probability

a=0.3,m=10,M=270,B=4500,V=2000

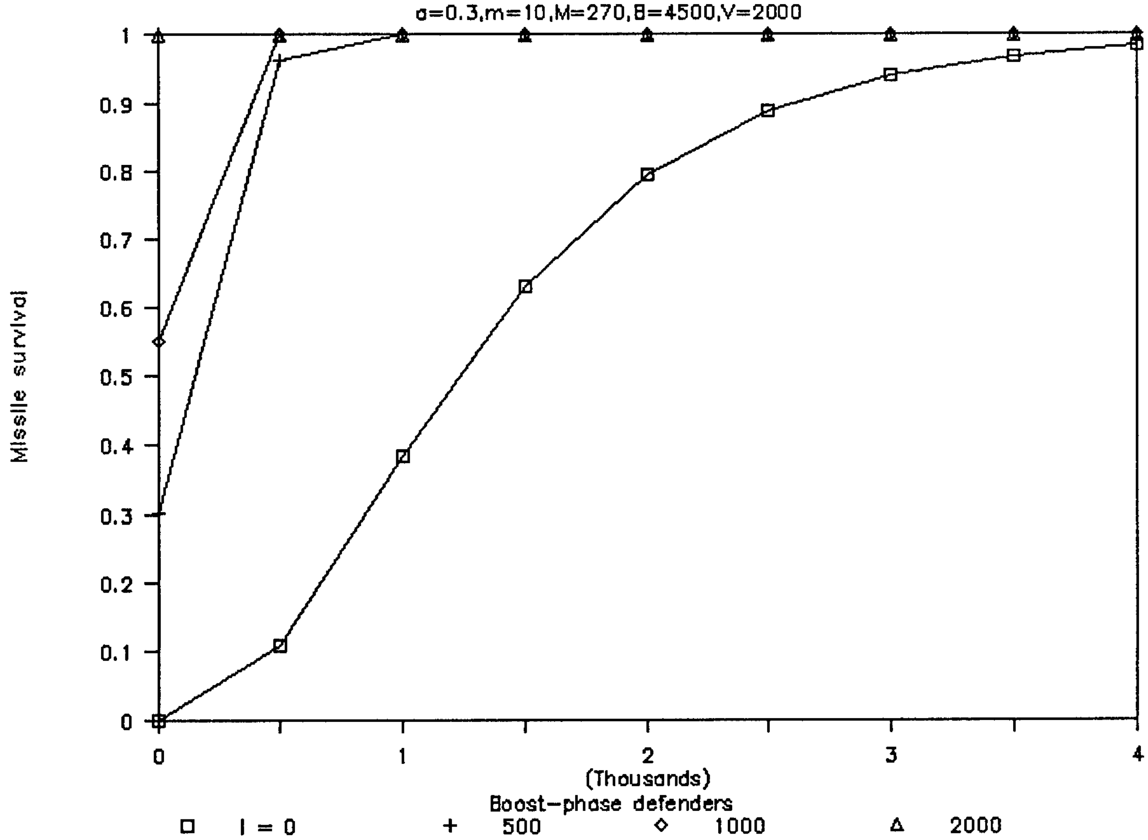

Fig. 7 Restrike ICBM penetration

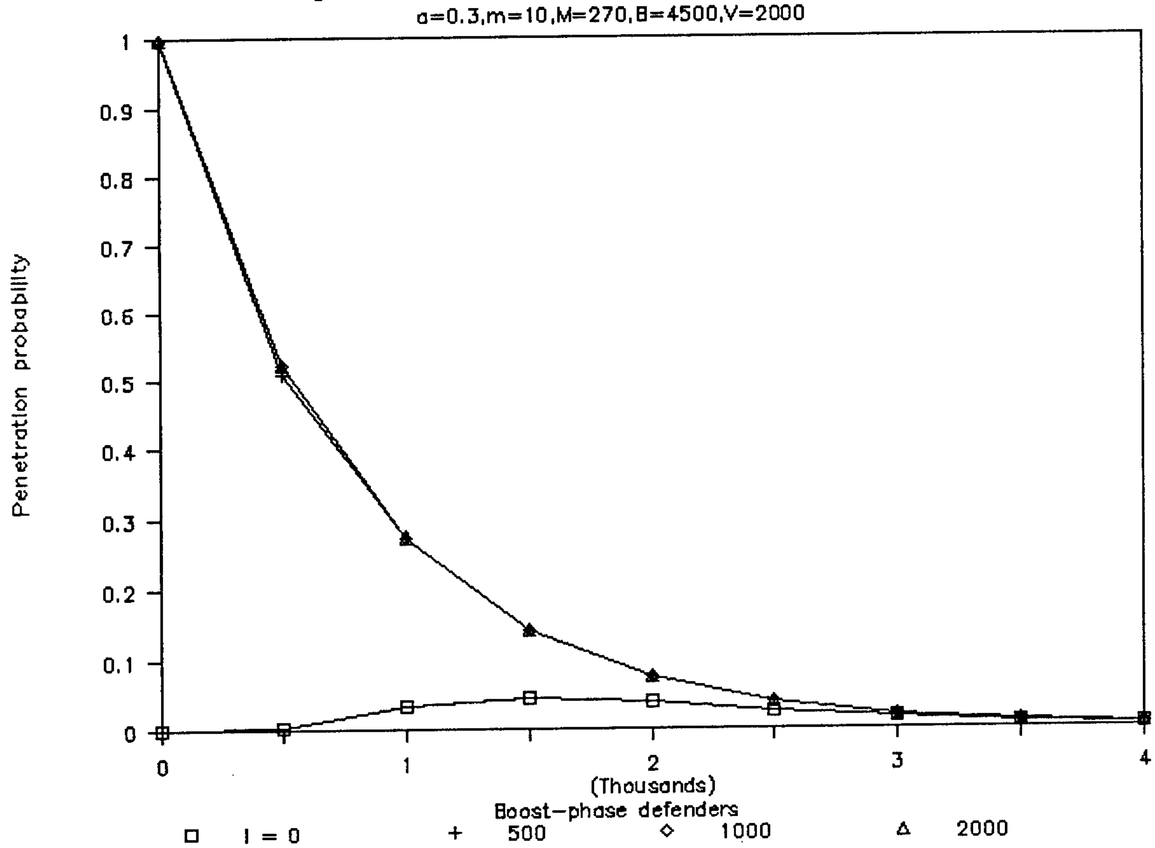

Fig. 8 Restrike ICBM survive &penetrate

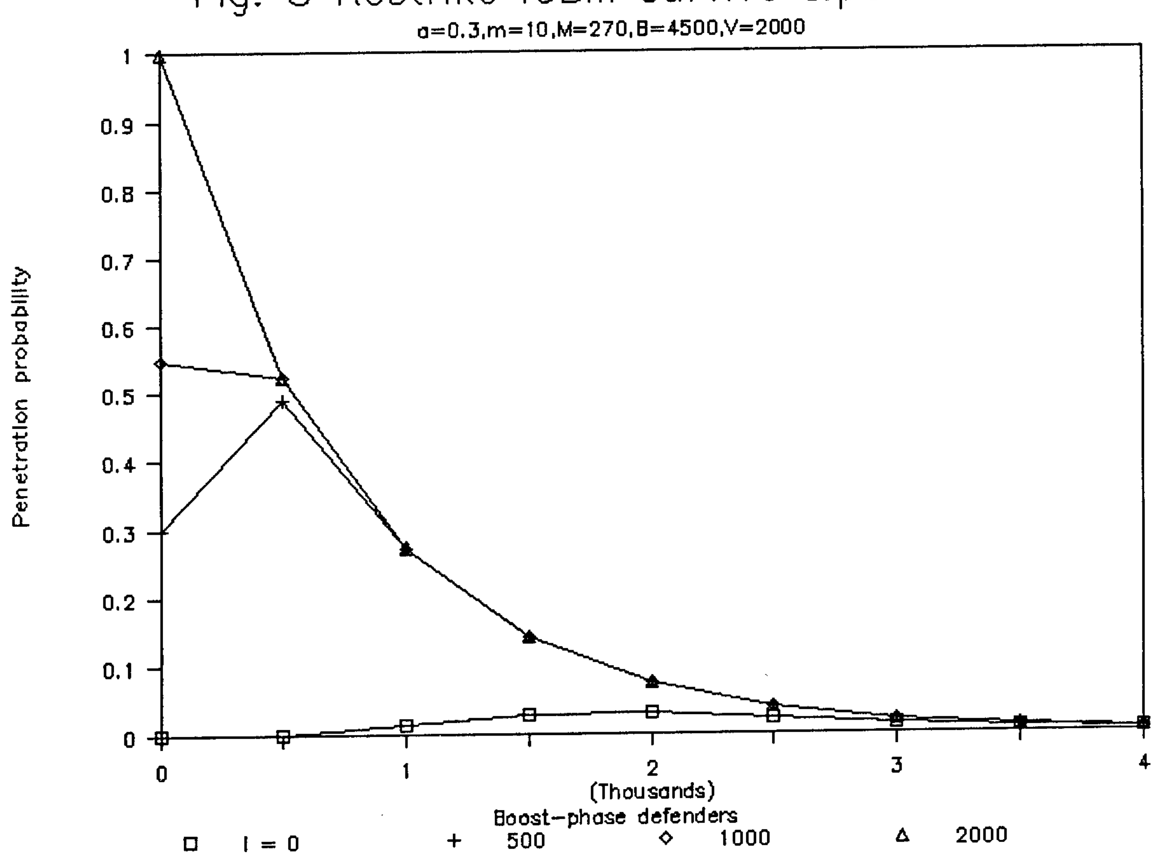

Fig. 9 Missile restrike on value

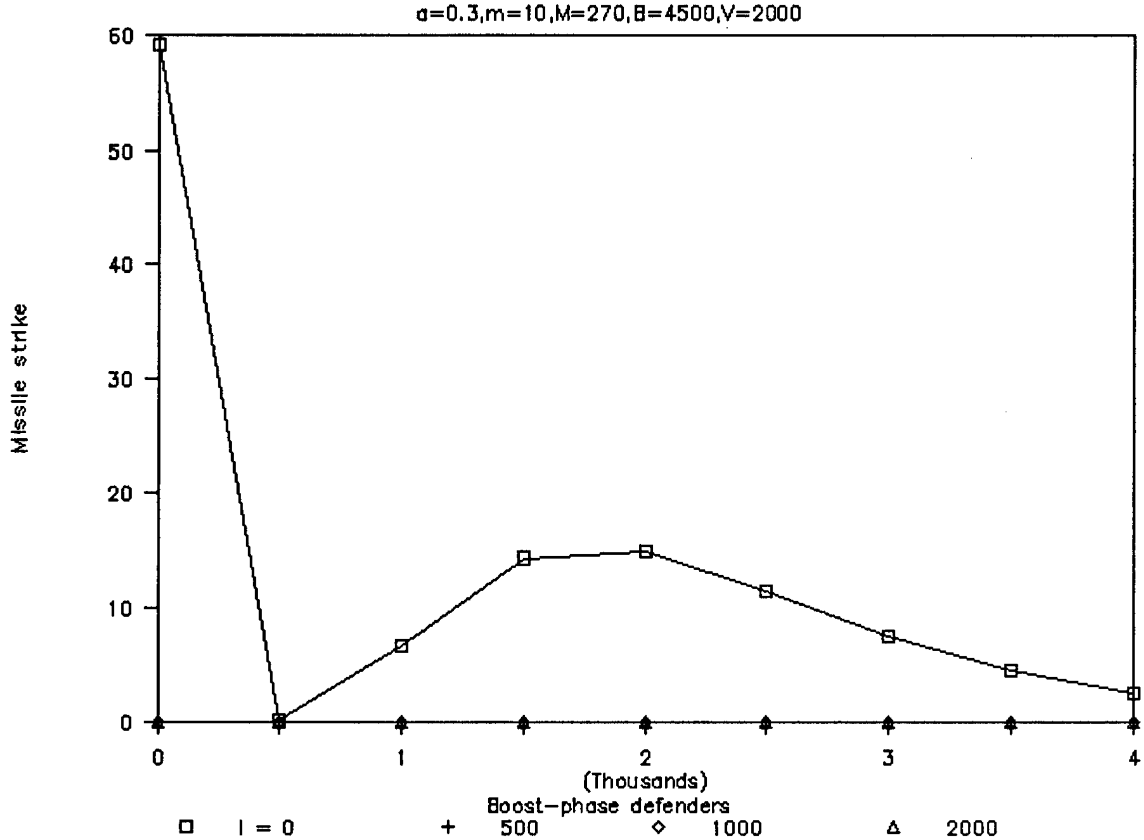

Fig. 10 Total restrike on value

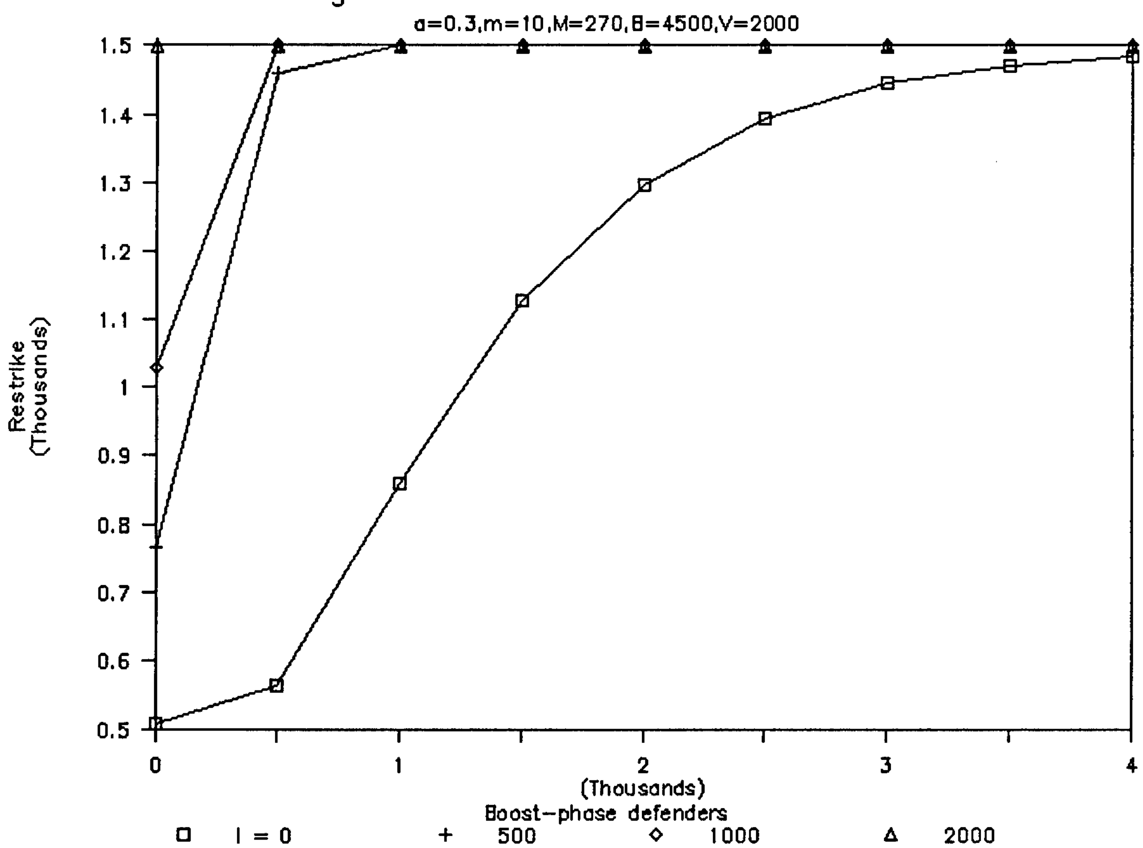

Fig. 11 Non-alert attack A/C survival

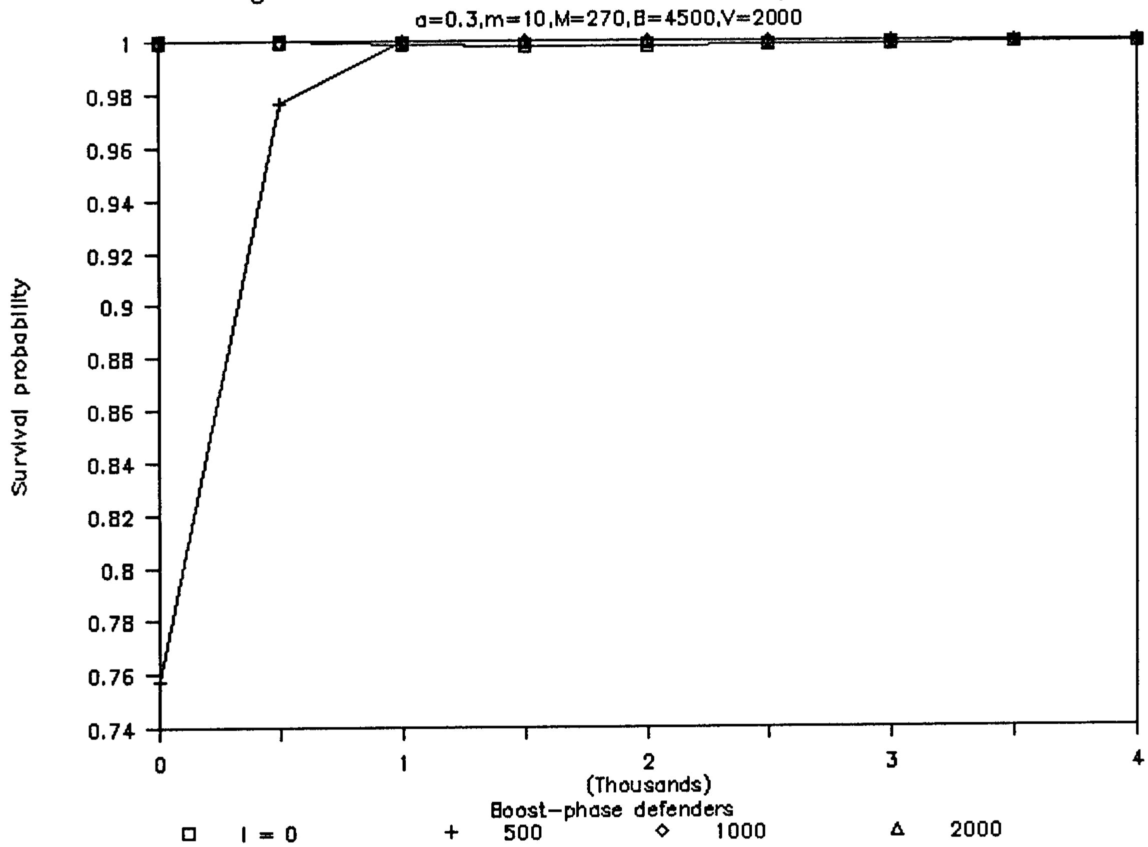

Fig. 12 First strike cost

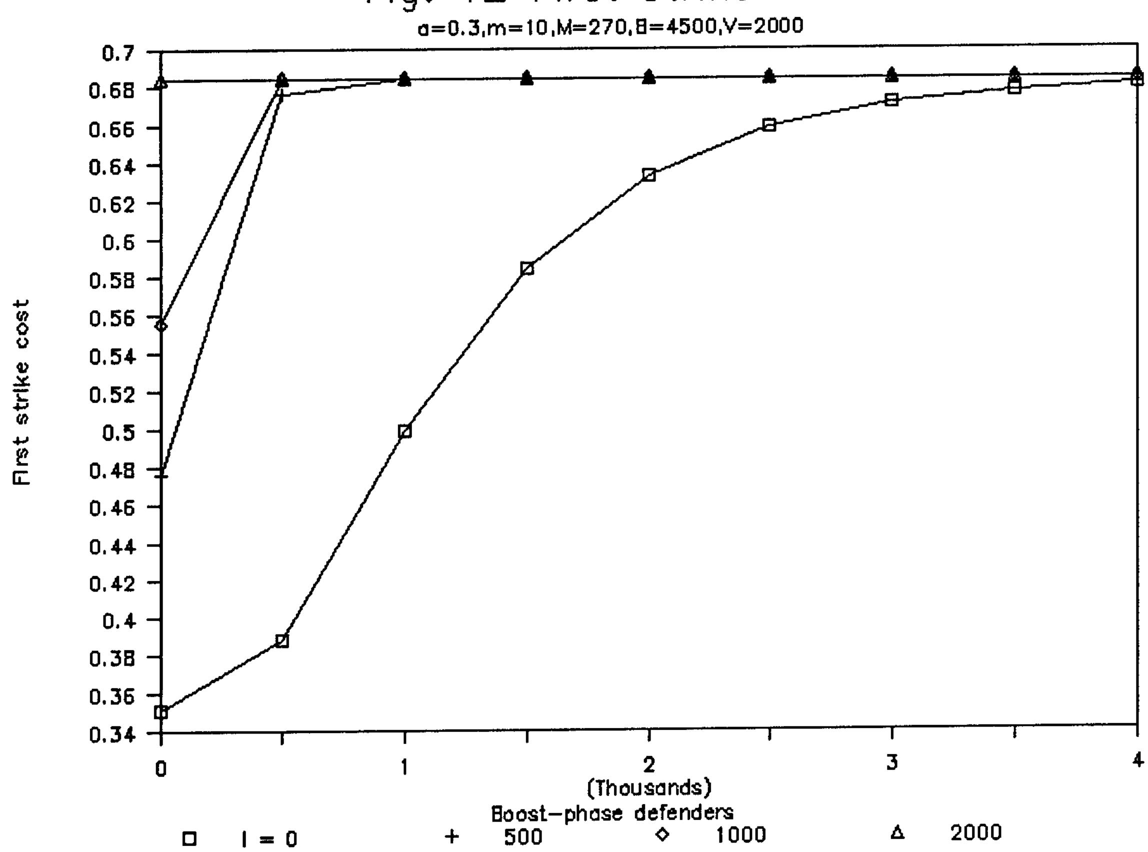

Fig. 13 Restrike cost

a=0.3,m=10,M=270,B=4500,V=2000

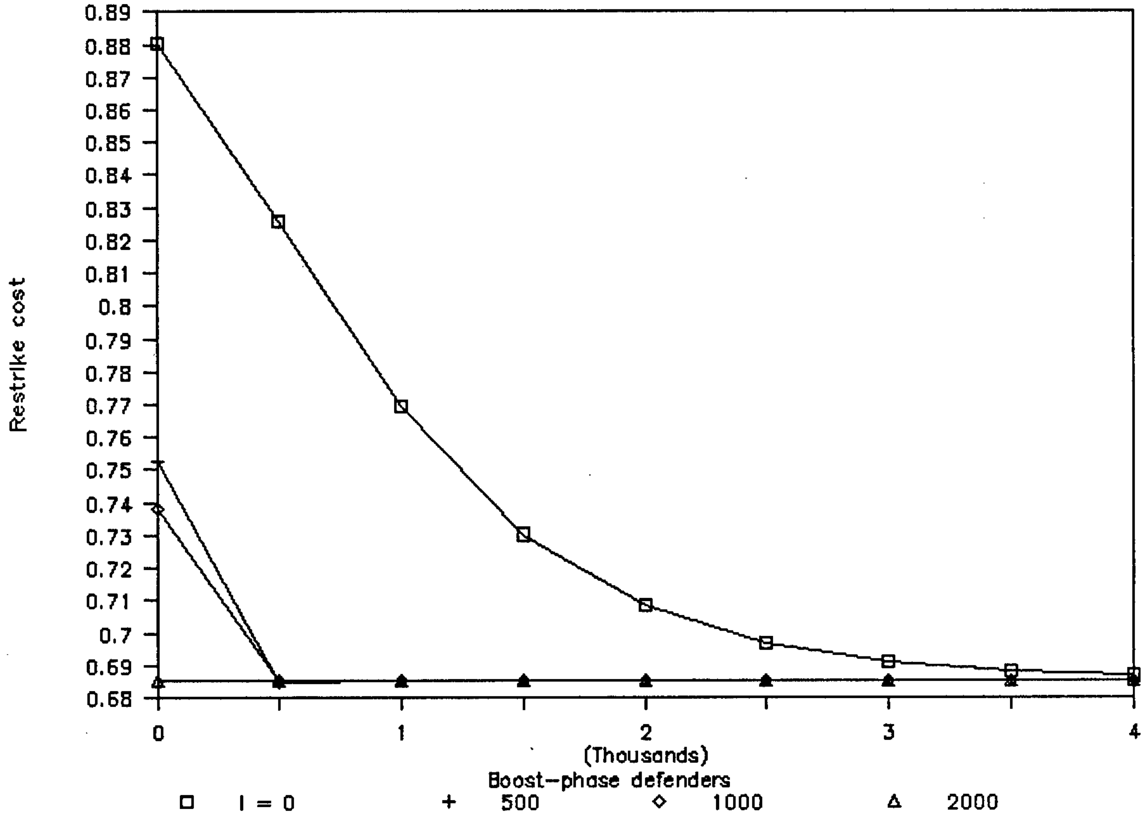

Fig. 14 Crisis stability index

a=0.3,m=10,M=270,B=400,V=2000

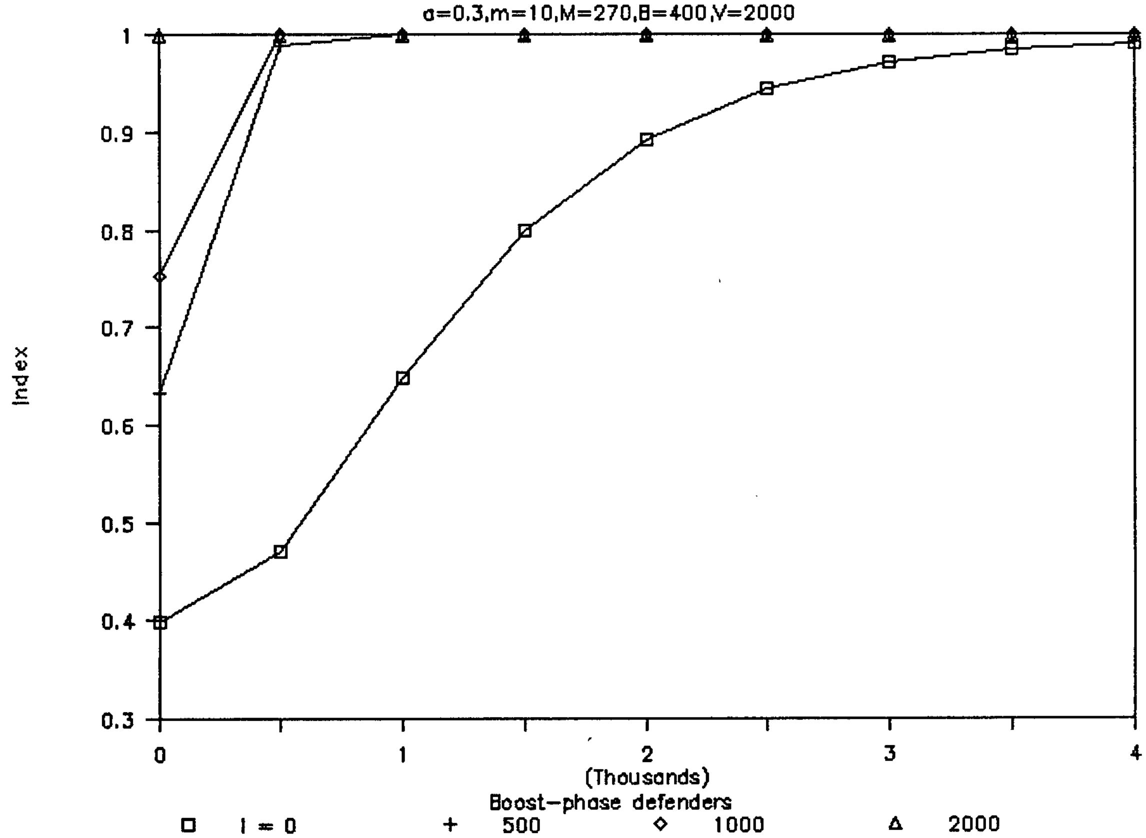

Fig. 15 Boost phase pen. probability

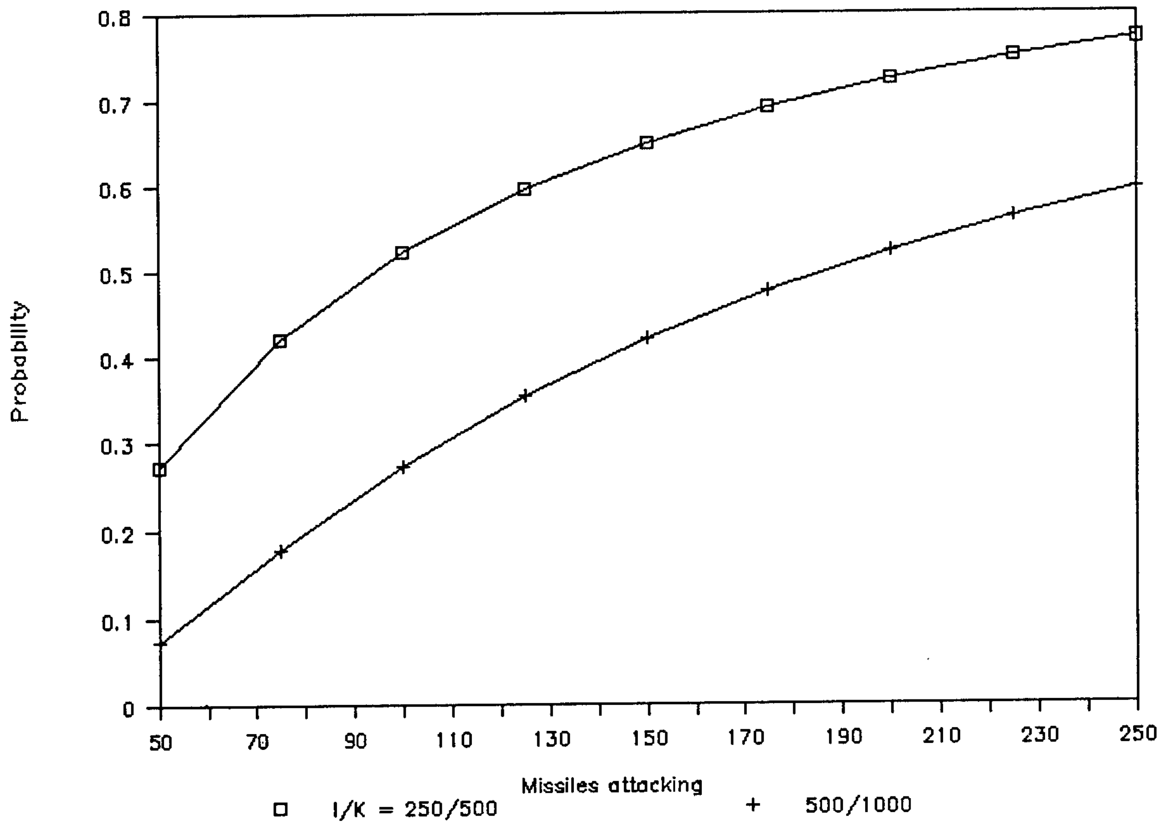

Fig. 16 Missile survival probability

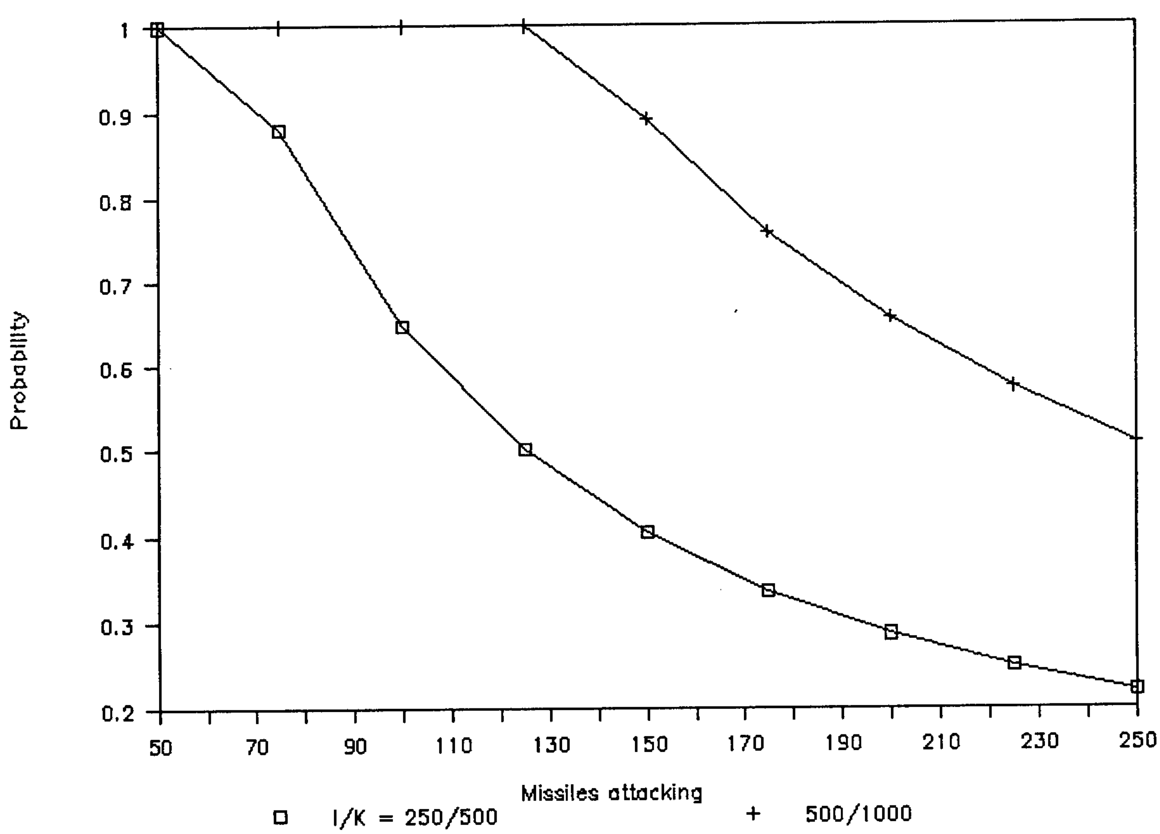

Fig. 17 Survival/pen. probability

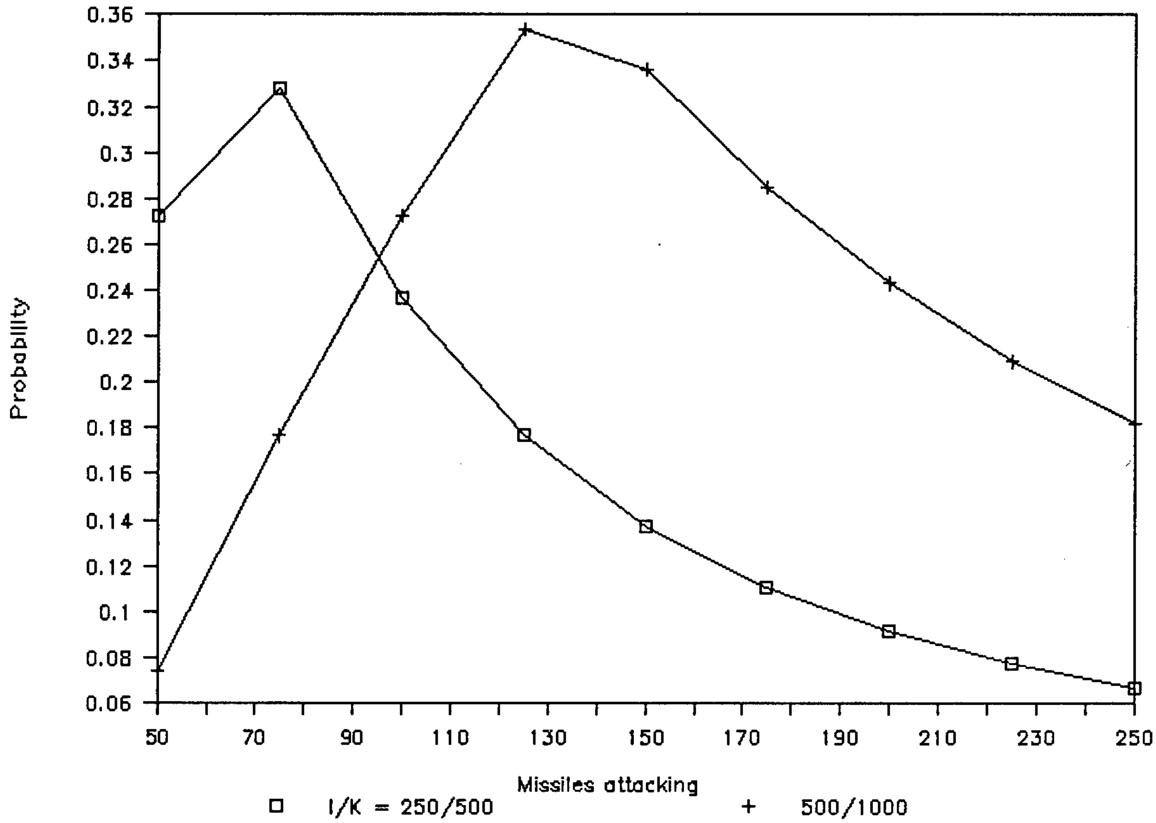

Fig. 18 A/C survival probabilities

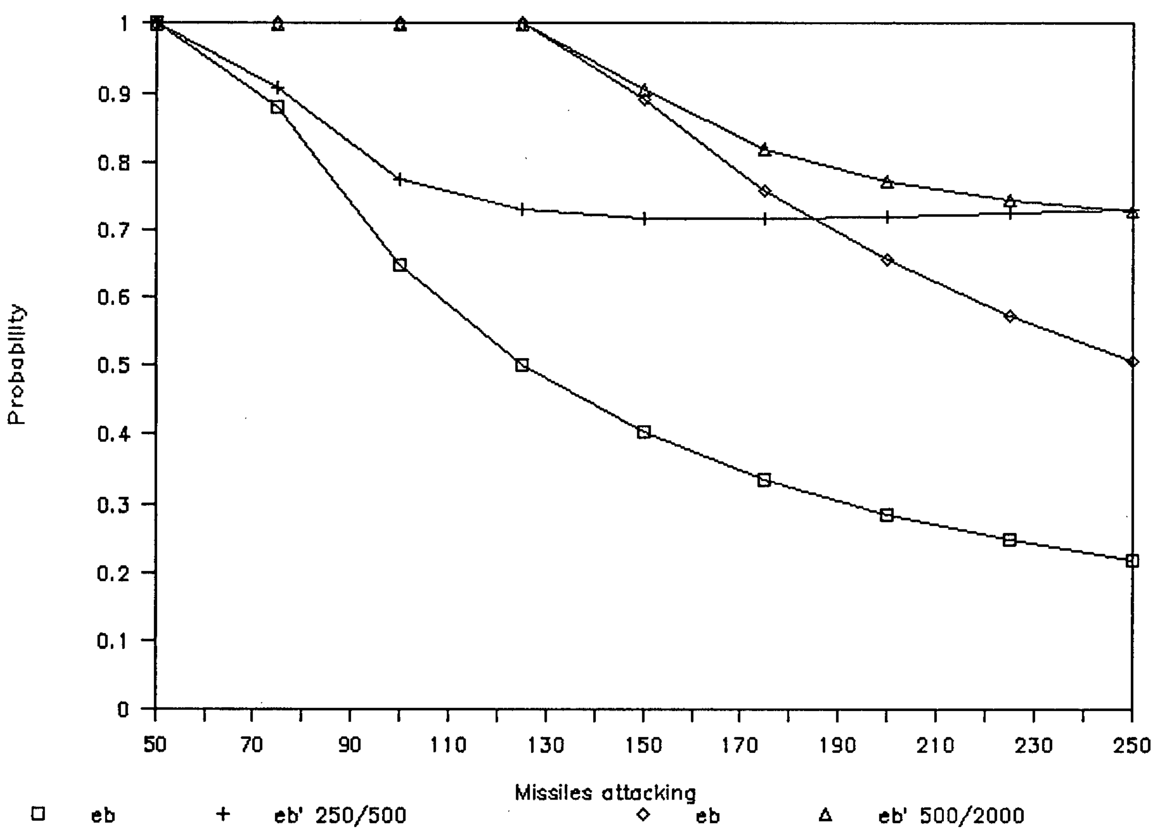

Fig. 19 Restriking RVs

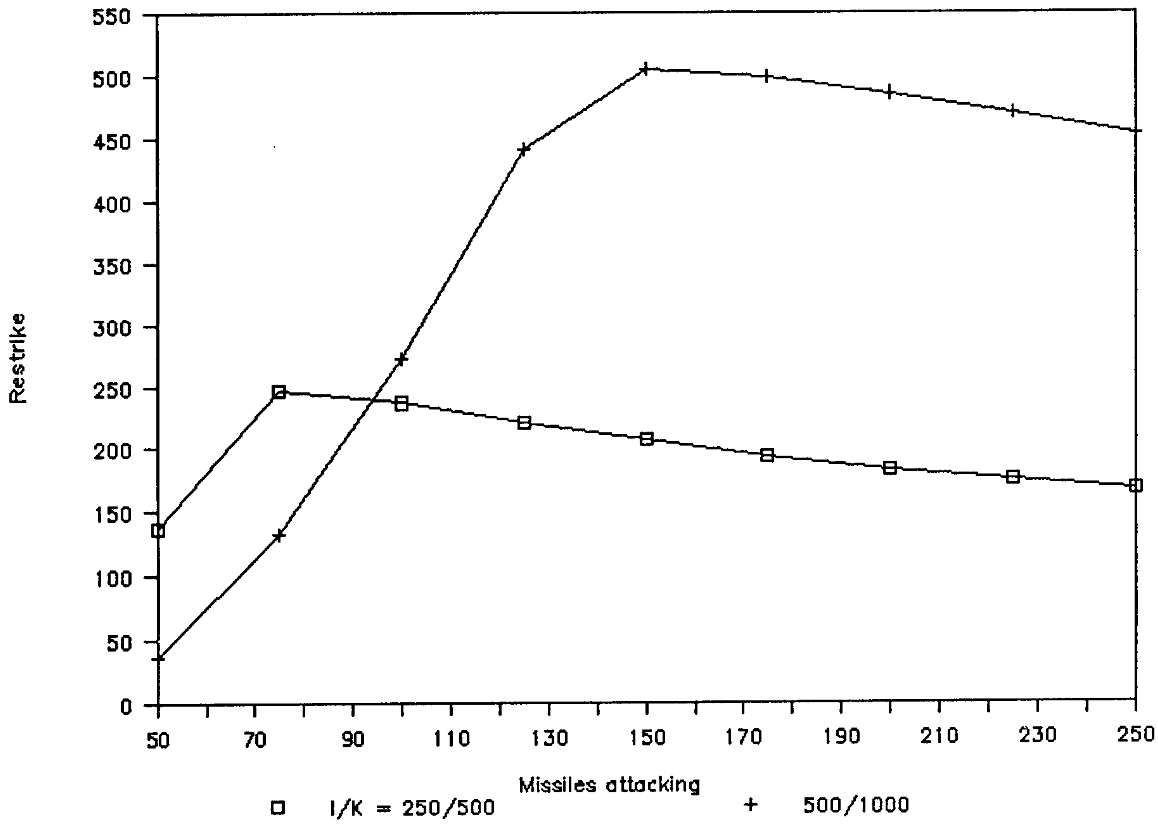

Fig. 20 First strike costs

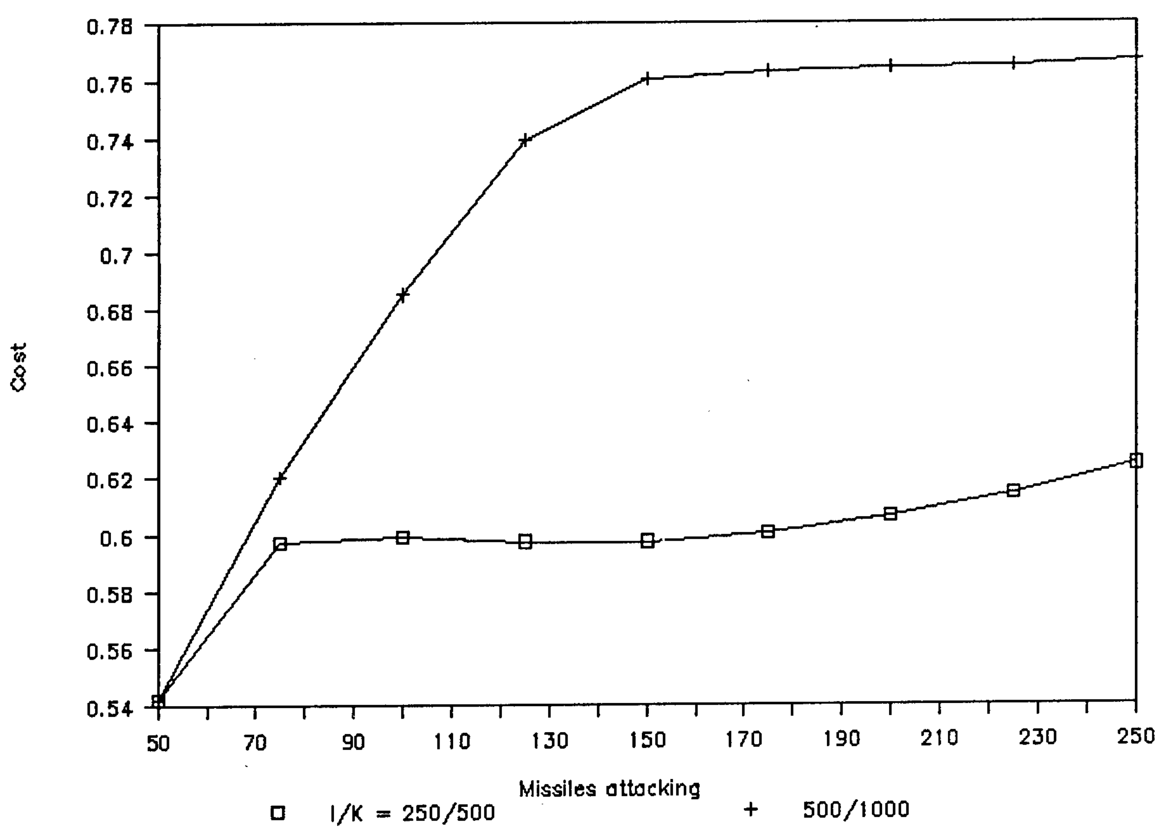

Fig. 21 Second strike costs

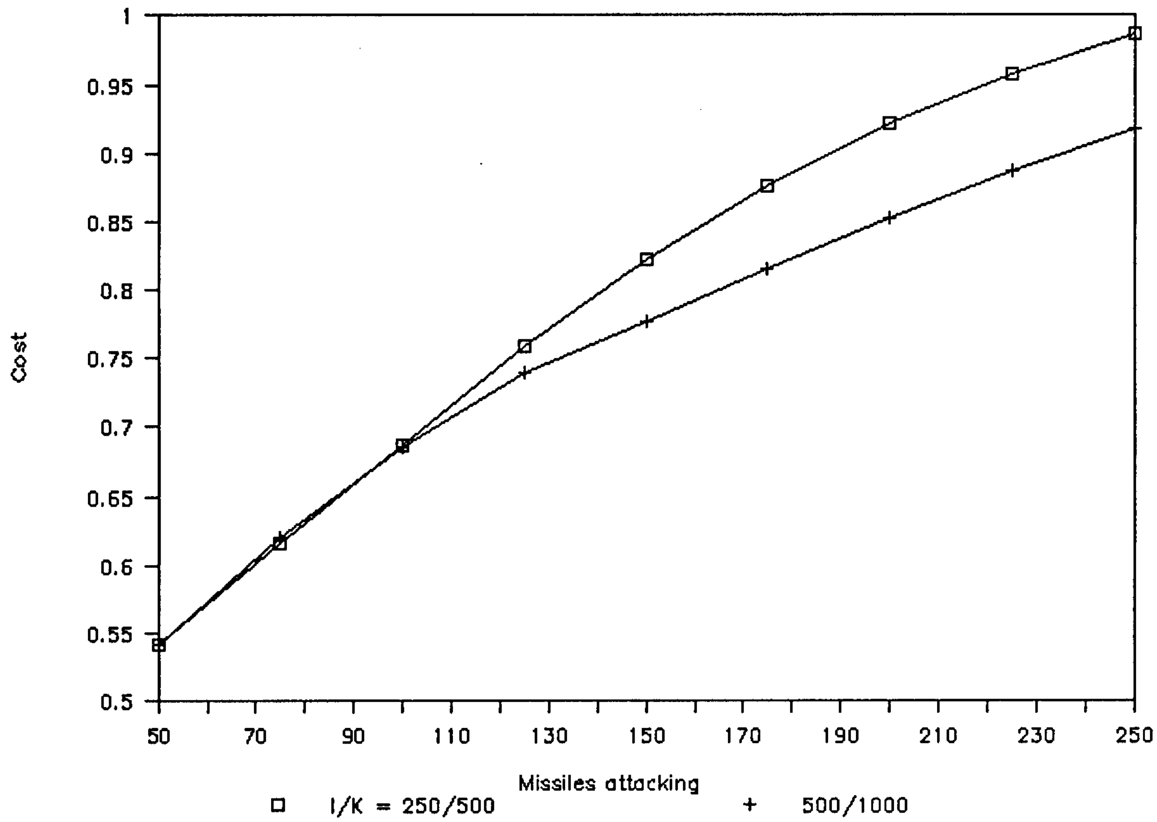

Fig. 22 Stability index

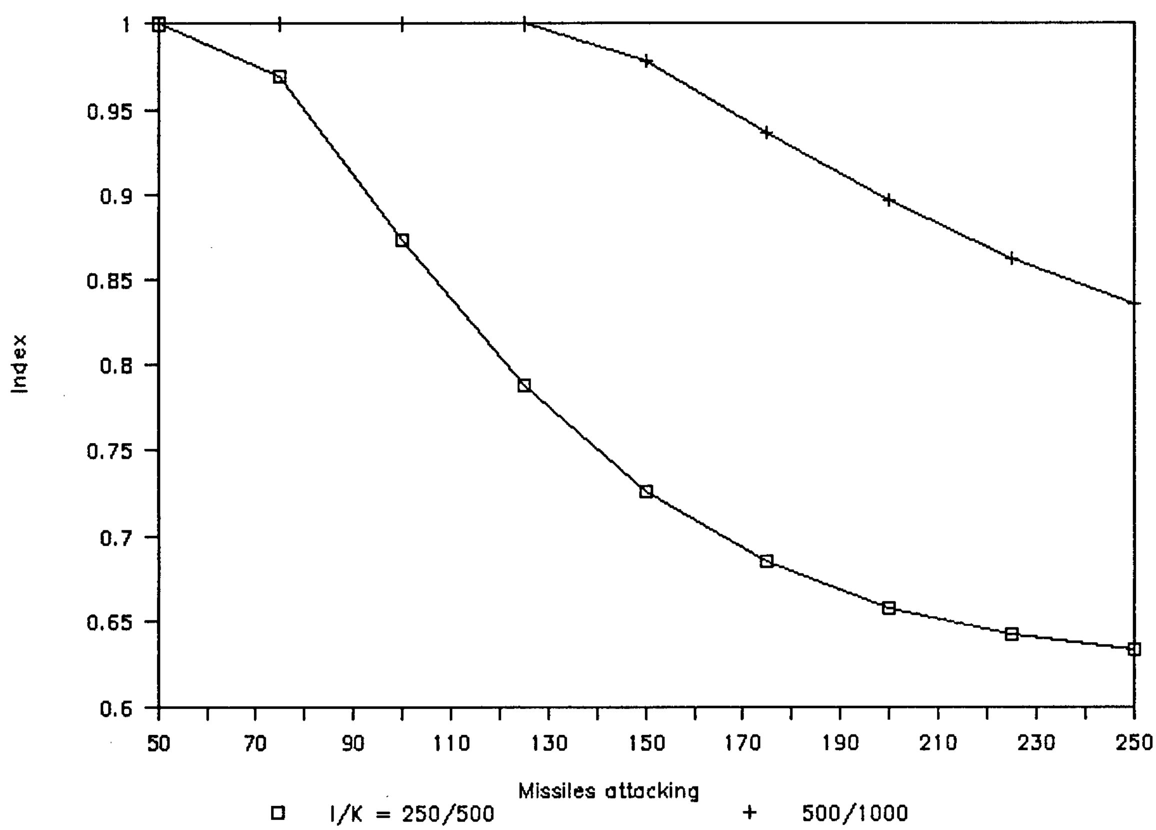

Fig. 23 Restriking RVs

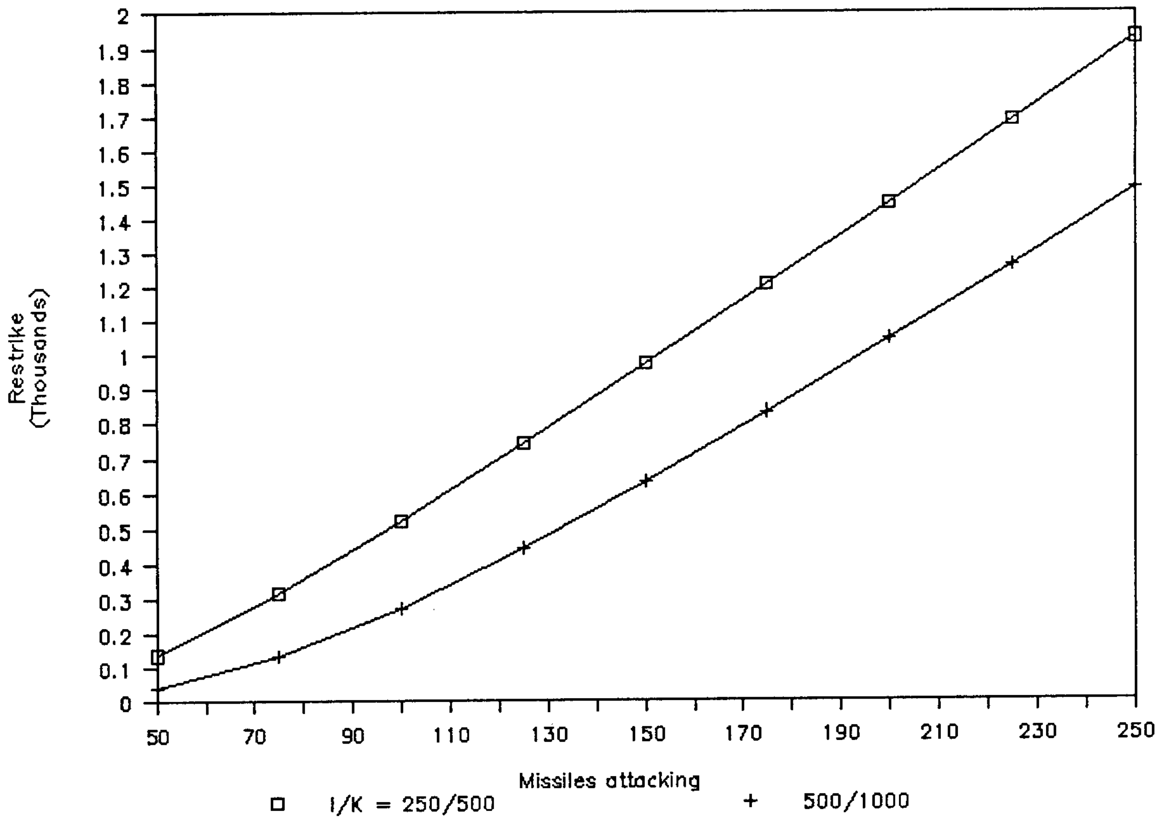

Fig. 24 Restrike

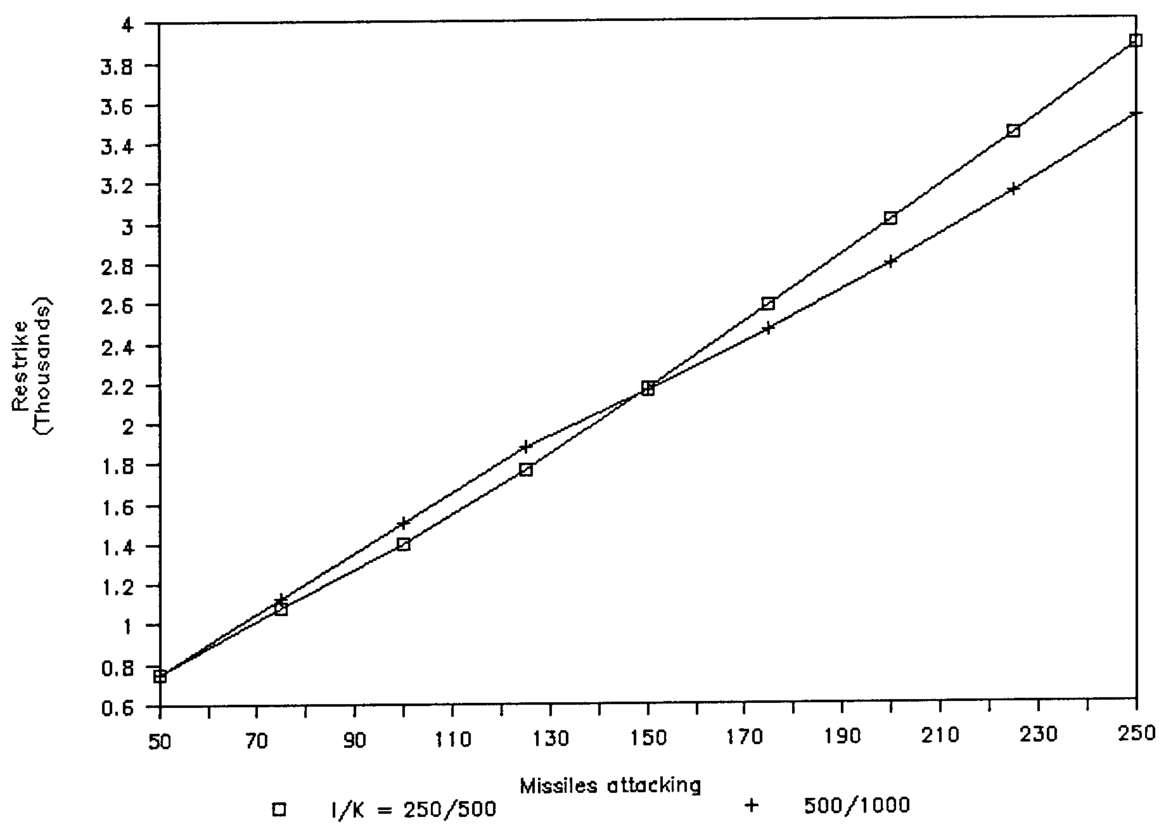

Fig. 25 First strike cost

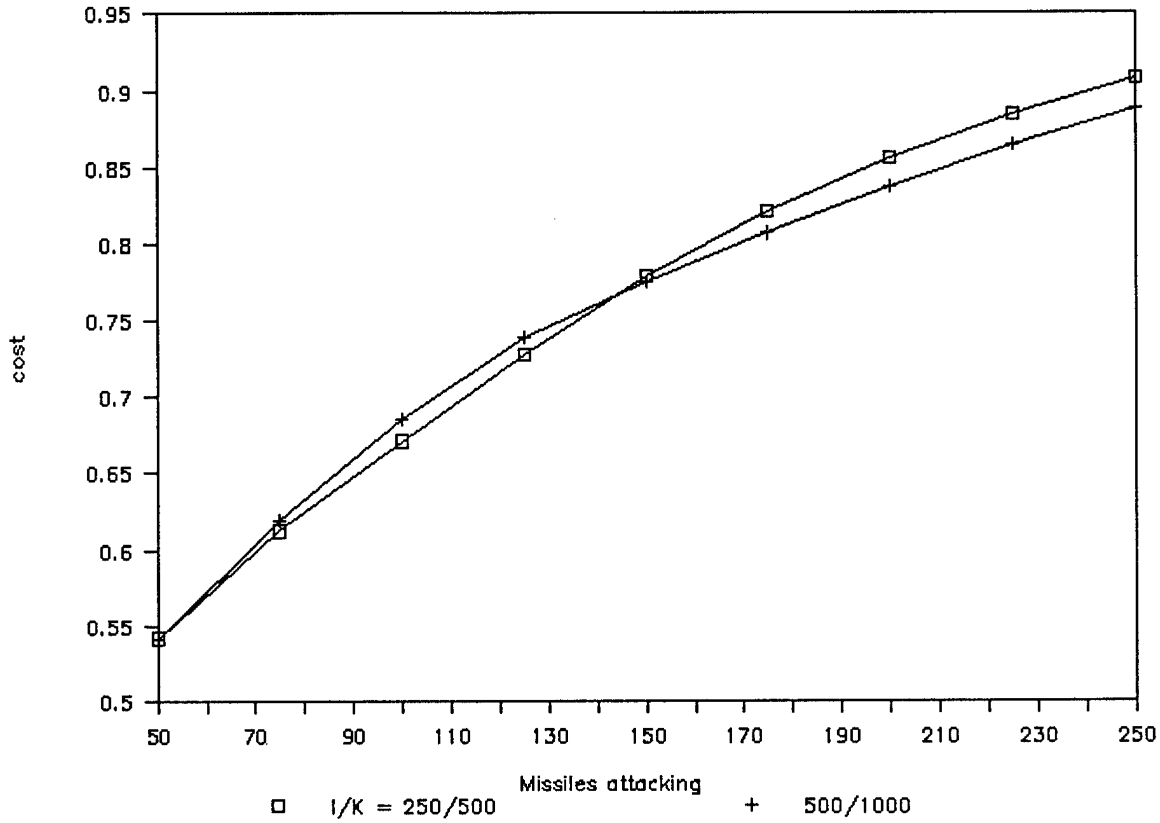

Fig. 26 Second strike cost

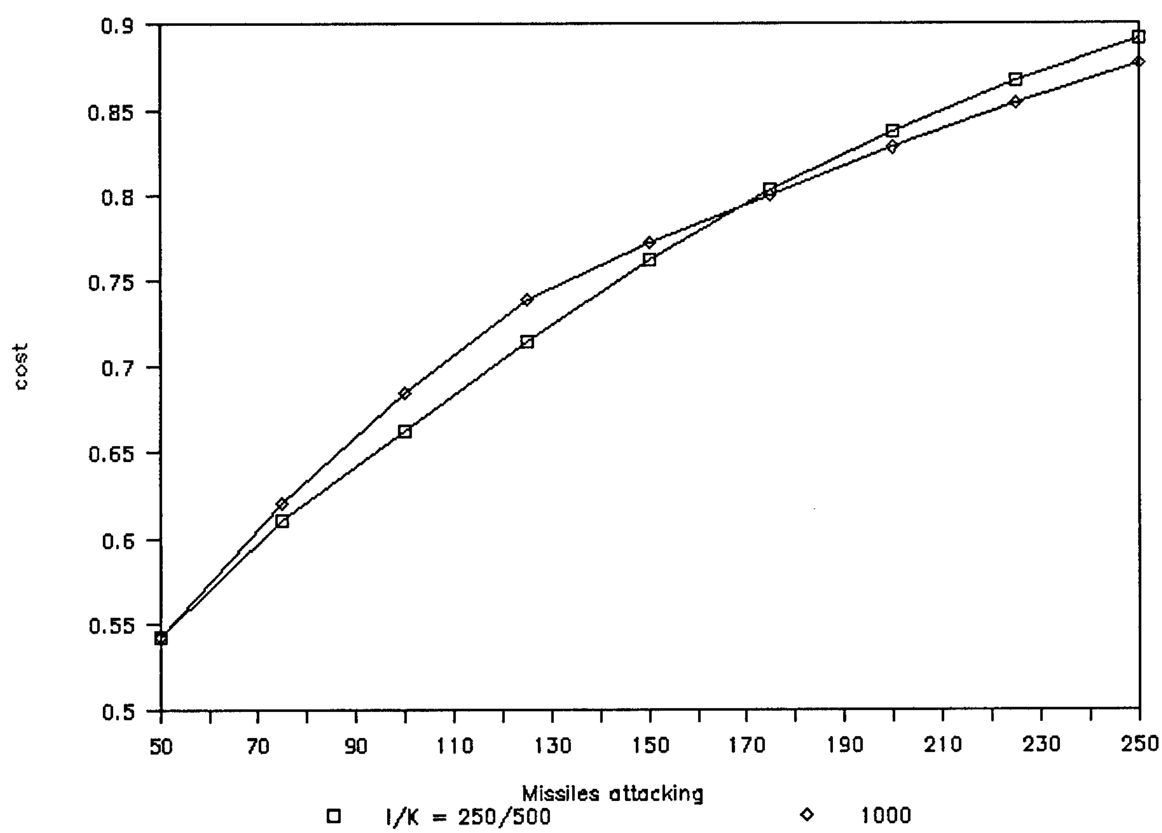

Fig. 27 Stability index